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D3.9 Country (per demo case) specific guideline packages for selected financial solution and optimal leverage ratios (SUPER-i leverage ratios) for all the 6 partner countries.

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1. Technical references

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RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

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Executive summary

This summary refers to Deliverable 3.9, which is part of Task 3.2 within Work Package 3 of the SUPER-i project. The purpose of this deliverable is to provide guidelines for specific financial solutions and optimal leverage ratios for six partner countries (Italy, Denmark, Slovenia, Spain, UK, and Belgium), with a focus on energy renovations in social housing. The guidelines consider technical, financial, environmental, and social aspects to align with the expected goals of the SUPER-I project and support the EU Commission in implementing the European Green Deal. By generating investments in energy efficiency within the social housing sector, the deliverable aims to contribute to the overall mission of the project by improving energy efficiency renovation projects.

The report draws on previous results from WP1 and WP2 and will continue to be developed over the coming months to reflect results in D3.10 in month 38. Ultimately, the deliverable will form a complete package of guidelines with a replicability approach within the EU housing framework.

This deliverable presents financial mechanisms and guidelines to promote the energy efficiency renovations in the social housing sector at EU level. The report emphasises the importance of complying with local and national policies and funding programs. The barriers of energy efficient investments are also explained and guidelines to set up a favourable framework to ensure private financing, co-financing investments and mobilising investments. A group of selected financial solutions have been described per country demo case, together with the analysis of the optimal leverage ratio calculation methodology, the factors that could influence an optimal leverage, risk assessment and interpretation of results.

On the technical part the European Energy Performance of Buildings Directive has been used as a framework to state the guidelines on technical considerations for building renovation, for the different countries. This directive sets out the requirements for energy performance of buildings towards reducing greenhouse gas emissions and promoting energy efficiency. Different building technologies and materials have been analysed together with energy efficiency measures and the integration of smart technologies towards the aim of the deliverable.

The environmental impact has been framed on EU legislation and describes some key terms on the matter for a better understanding of the evaluation methodology and guidelines suggested for its implementation as an assessment methodology in each country. Life Cycle Assessment and Social Life Cycle Assessment have been described pointing out their relationship with the Environmental and Social KPIs developed on deliverable 3.2. To finalise an analysis on environmental regulations per demo case have been presented.

3. Introduction

The SUPER-i project will provide a significant contribution to generating investments and collecting data on energy efficiency in building renovation in the social housing sector, an initiative supported by the EU "clean energy for all Europeans framework". It will contribute to generating significant social impact by reducing energy poverty through energy efficiency (EE) renovations of social housing while supporting the European Green Deal working towards a decarbonised Europe.

The purpose of this deliverable presents specific guidelines packages for selected financial solutions and the optimal leverage ratios for 6 partner countries: Italy, Denmark, Slovenia, Spain, UK, and Belgium, with a focus on energy renovations in social housing. To do so, technical, environmental, and social aspects have been taken into consideration with a holistic approach for better decisions on energy efficiency renovation projects on the social housing frame.

4. Country-Specific Guidelines for Financial Solutions

The European Union (EU) has been actively promoting energy efficiency renovations in social housing through various financial mechanisms and guidelines to promote energy efficiency and sustainability in social housing while addressing energy poverty and improving living conditions for vulnerable communities. Local implementation and coordination with national policies and funding programs are essential to ensure effective utilisation of funding and achieve the desired outcomes in energy efficiency renovations. EU funding programmes will ensure direct co-financing of investments in energy efficiency and leverage private and public investments through tailored financial instruments and project development assistance.

To reduce greenhouse gas emissions by 55% by 2030 (compared to 1990 levels), the stakeholders need to invest an estimated €392 billion more each year in the energy system than in the period 2011-2020. Energy efficiency faces one of the largest investment gaps, estimated at around €165 billion annually. Moreover, energy efficiency investments face several barriers:

- Fragmented market,
- Complex decision-making processes
- Split incentives.
- Lack of knowledge and data about the benefits of energy efficiency improvements and the related uncertainties.

Therefore, setting favourable framework conditions is necessary to ensure private financing supply to investments in energy efficiency of buildings, industry, transport, and other sectors. This process takes place in the broader context of the EU policy focus on Sustainable Finance and the development of the Strategy for Financing the Transition to a Sustainable Economy, which also covers the financing framework for energy efficiency investments. Also, energy efficient building renovations can be expensive, and owners may not have the means to finance them therefore financial instruments provided by EU countries, the European Investment Bank (EIB) and the EU itself, can help solve this issue and address financial and investment gaps.

Co-financing investments:
The Commission's multiannual financial framework 2021-2027 and the NextGenerationEU instrument will directly co-finance energy efficiency investments in the EU through 3 different funds:

Recovery and Resilience Facility: This instrument will be the main source of public funding for energy efficiency in the coming years. It will focus on public buildings and residential buildings, including social housing. From the €672.5 billion in total, 37% should go to climate action. Based on the Recovery and Resilience plans submitted by EU countries, energy efficiency and building renovation are key components in almost all plans. The Recovery and Resilience Facility is at the heart of the REPowerEU plan implementation, providing additional EU funding. EU countries can use the remaining Recovery and Resilience Facility loans (currently €225 billion) and new grants funded by the auctioning of Emission Trading System allowances, currently held in the Market Stability Reserve, worth €20 billion. EU countries should also add a REPowerEU chapter to their Recovery and Resilience Plans to channel investments to REPowerEU priorities and make the necessary reforms.

Cohesion policy funds: These include the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, the Just Transition Fund and INTERREG. The total budget of €373 billion will be a key source of funding for direct investments in energy efficiency.

Modernisation Fund: This fund was established under the Emissions Trading Scheme Directive. It has a total budget of around €14 billion, available to 10 lower-income EU countries to support investments in the modernisation of their energy systems and energy efficiency improvements.

Mobilising investment:
InvestEU acts as a single investment support mechanism with an EU budget of €26.2 billion. It aims to leverage €370 billion, replacing all the existing centrally managed financial instruments and gathering technical assistance support under the common umbrella of its Advisory Hub. InvestEU aims to mobilise public and private financing in the form of loans, guarantees, equity or other market-based instruments for strategic investments to support EU internal policies. It is divided into 4 policy windows: sustainable infrastructure (€ 9.9 billion); research, innovation, and digitisation (€ 6.6 billion); SMEs (€ 6.9 billion); social investment and skills (€ 2.8 billion). Energy efficiency will be supported under all 4 windows, but mainly under sustainable infrastructure.

4.1. Denmark

4.1.1. Selected Financial Solutions

In the case of Denmark, several funding sources are available such as:

Energy Savings Agreements (ESA): Denmark's Energy Savings Agreements (ESA) program embodies a proactive approach to fostering energy efficiency in buildings. ESA is a collaborative effort between the government and businesses, aiming to achieve significant reductions in energy consumption over time. Through ESA, companies commit to implementing energy-saving measures in their buildings, with targets set for reducing energy usage by a certain percentage within a defined period. Participating companies receive invaluable support in the form of financial incentives and technical expertise to facilitate the implementation of energy efficiency measures. This support can include subsidies for energy audits, grants for equipment upgrades, and access to resources for training and capacity building. By engaging businesses directly in the pursuit of energy efficiency, ESA drives innovation, fosters knowledge-sharing, and cultivates a culture of sustainability within the private sector. ESA is a testament to Denmark's collaborative and pragmatic approach to addressing energy challenges. By harnessing the collective efforts of government, industry, and other stakeholders, ESA paves the way for substantial energy savings, cost reductions, and environmental benefits in buildings across the country.

Green Loans and Subsidies: Denmark's provision of green loans and subsidies represents a proactive strategy to overcome financial barriers and incentivize energy efficiency renovations in buildings. Green loans offer favourable terms, such as low-interest rates and flexible repayment options, to encourage property owners to invest in energy-saving upgrades. These loans can be used to finance a wide range of renovations, including insulation improvements, heating system upgrades, and the installation of energy-efficient windows and doors. In addition to green loans, Denmark provides subsidies to further offset the costs of energy efficiency projects. These subsidies help make energy renovations more accessible and affordable for homeowners, housing associations, and businesses, particularly those with limited financial resources. By reducing the upfront investment required for energy-saving measures, subsidies stimulate demand and accelerate the adoption of sustainable building practices. Green loans and subsidies exemplify Denmark's commitment to supporting individuals and organisations in their transition to a more energy-efficient future. By providing financial incentives and removing financial barriers, Denmark empowers property owners to make investments that not only enhance the comfort and value of their buildings but also contribute to national energy and climate goals.

Energy Renovation Subsidies: Denmark's energy renovation subsidies play a crucial role in promoting energy efficiency in buildings by providing financial assistance to cover the costs of renovation projects. These subsidies are specifically targeted at energy-saving measures, such as insulation upgrades, HVAC system improvements, and the installation of renewable energy technologies. One key aspect of energy renovation subsidies is their support for energy audits and planning activities. By offering financial assistance for the initial assessment and planning stages of renovation projects, Denmark helps property owners identify cost-effective energy-saving opportunities and develop comprehensive renovation plans. Energy renovation subsidies make energy efficiency renovations more affordable and accessible for homeowners, housing associations, and businesses across Denmark. By reducing the financial burden associated with energy renovations, these subsidies encourage greater uptake of sustainable building practices, leading to lower energy consumption, reduced carbon emissions, and improved building performance. Denmark's commitment to providing energy renovation subsidies underscores its dedication to promoting sustainable development and combating climate change. By investing in energy efficiency in buildings, Denmark not only enhances the quality and comfort of its built environment but also contributes to global efforts to create a more resilient and sustainable future.

The National Building Fund (NBF): operates as an autonomous entity with its dedicated board. This fund comprises substantial resources, constituting approximately 15% to 20% of the housing stock in Denmark, contributing to its financial pool. Its investment activities are subject to legal regulations. During the financial crisis, the NBF played a crucial role in stimulating the Danish economy by facilitating increased renovation activities. This approach funnelled additional resources into the construction industry, leading to the creation of more jobs and, consequently, fostering economic growth. As the original construction loans are paid off, housing departments or organisations continue their payments initially to the state and subsequently to The National Building Fund. The fund is structured into distinct components, namely the Revolving Renovation Fund (RRF), the housing organisation's own disposition fund, and a fund designated for new construction. The RRF within the NBF serves a specific and well-defined purpose, yet tenants also have the option to directly initiate renovations for their homes.

*Tax Credits and Deductions***:** Denmark's tax credits and deductions for energy efficiency renovations offer financial incentives to individuals and businesses to invest in sustainable building upgrades. Property owners can deduct eligible expenses related to energy renovations from their taxable income or claim tax credits for specific energy-saving measures implemented in their buildings. These tax incentives reduce the overall cost of energy efficiency renovations and provide a tangible financial benefit to property owners. By lowering the financial barrier to entry, tax credits and deductions encourage greater investment in energy-saving technologies and practices, leading to long-term energy and cost savings. In addition to stimulating demand for energy efficiency renovations, tax credits and deductions also help drive innovation and market development in the sustainable building sector. By rewarding investments in energy efficiency, Denmark creates a favourable environment for the growth of businesses that provide products and services related to sustainable construction and renovation. Denmark's use of tax incentives to promote energy efficiency in buildings exemplifies its commitment to fostering a green economy and reducing greenhouse gas emissions. By leveraging the tax system to incentivize sustainable building practices, Denmark encourages individuals and businesses to play an active role in the transition to a low-carbon future.

Public Funding Programs: Denmark's allocation of public funding for energy efficiency projects demonstrates its commitment to supporting sustainable development and combating climate change. These public funding programs provide financial assistance to individuals, businesses, and organisations undertaking energy efficiency renovations in buildings. Public funding programs may take various forms, including grants, loans, and subsidies, and may be administered at the national, regional, or local level. They aim to make energy efficiency renovations more affordable and accessible, particularly for those facing financial constraints or operating in sectors with high energy consumption. By investing in energy efficiency projects, Denmark not only reduces energy consumption and greenhouse gas emissions but also stimulates economic growth and job creation. Public funding programs support innovation, technology development, and market transformation in the sustainable building sector, driving forward Denmark's transition to a low-carbon economy. Denmark's commitment to providing public funding for energy efficiency renovations reflects its recognition of the importance of sustainable buildings in achieving its environmental and economic goals. By leveraging public resources to support energy efficiency initiatives, Denmark demonstrates leadership in addressing climate change and building a more resilient and prosperous future.

Energy Performance Contracts (EPC): Denmark's use of Energy Performance Contracts (EPCs) offers an innovative financing mechanism for energy efficiency renovations in buildings. Under an EPC arrangement, an energy service company (ESCO) finances, implements, and maintains energy-saving measures in a building, with the property owner repaying the investment over time through the energy cost savings generated by the renovations. EPCs provide a risk-free and cost-effective way for building owners to upgrade their properties without the need for upfront capital investment. By outsourcing the financing and implementation of energy efficiency measures to an ESCO, building owners can benefit from immediate energy savings and improved building performance without incurring additional debt or financial strain. In addition to financial benefits, EPCs also offer technical expertise and ongoing support to ensure the long-term success of energy efficiency projects. ESCOs often provide monitoring and maintenance services to optimise energy performance and maximise savings over the contract term. Denmark's adoption of EPCs reflects its commitment to promoting energy efficiency and sustainability in the built environment. By leveraging private sector expertise and financing, EPCs offer a scalable and replicable solution for driving energy efficiency renovations in buildings and advancing Denmark's transition to a low-carbon future.

4.2. Italy

4.2.1. Overview of Selected Financial Solutions

Italy has various funding sources and support mechanisms for social housing energy efficiency (EE) renovation projects. Here are some potential funding sources for social housing EE renovation projects in Italy:

Ecobonus and Sismabonus: Promoting Energy Efficiency and Safety in Italian Buildings:

Italy's Ecobonus and Sismabonus initiatives stand as cornerstone policies in the nation's efforts to enhance energy efficiency and ensure the safety of its buildings. Introduced as tax incentives, these programs incentivize property owners to undertake renovations that not only reduce energy consumption but also improve seismic resilience. The Ecobonus program offers tax deductions to individuals and businesses investing in energy-efficient upgrades for their buildings. These upgrades encompass a wide range of measures, including but not limited to insulation, efficient heating and cooling systems, and the installation of renewable energy technologies. By providing financial incentives, the government aims to spur investment in sustainable infrastructure, lower energy bills for property owners, and decrease Italy's overall carbon footprint. In parallel, the Sismabonus initiative addresses Italy's vulnerability to seismic events by promoting seismic retrofitting of buildings. Through tax incentives similar to the Ecobonus, property owners are encouraged to reinforce their structures to withstand earthquakes, thereby enhancing public safety and mitigating the impact of natural disasters. Together, the Ecobonus and Sismabonus initiatives exemplify Italy's commitment to fostering resilience and sustainability in its built environment. By harnessing the power of fiscal policy to drive positive change, the government empowers citizens to contribute to a more sustainable future while simultaneously safeguarding lives and property against seismic risks.

Superbonus 110%: Revolutionising Energy Efficiency Renovations in Italy: Italy's Superbonus 110% program represents a groundbreaking approach to incentivizing energy efficiency renovations in buildings. Introduced in 2020, this initiative offers a remarkable 110% tax credit for eligible renovation expenses, effectively covering the entire cost of the project and providing an additional incentive for property owners to invest in sustainability. Unlike traditional tax deductions, which offer partial relief from tax liabilities, the Superbonus 110% provides a tax credit that exceeds the amount spent on renovations. This revolutionary approach not only eliminates the financial burden associated with energy efficiency upgrades but also offers a tangible financial benefit to property owners. The Superbonus 110% is applicable to a wide range of renovation measures, including energy-efficient heating and cooling systems, insulation, photovoltaic systems, and seismic retrofitting. By encompassing both energy efficiency and safety enhancements, the program addresses multiple societal needs, ranging from climate action to disaster resilience. Moreover, the Superbonus 110% extends beyond residential properties to include commercial and public buildings, further amplifying its impact on Italy's built environment. By encouraging widespread adoption of sustainable practices across all sectors, the program accelerates progress towards national energy and climate goals while stimulating economic growth and job creation. In essence, Italy's Superbonus 110% program represents a paradigm shift in the approach to energy efficiency renovations, transforming what was once perceived as a financial burden into a compelling opportunity for sustainable investment and societal advancement.

Energy Efficiency Fund: Catalysing Sustainable Development in Italy: Italy's Energy Efficiency Fund plays a pivotal role in catalysing sustainable development and fostering a transition to a low-carbon economy. Established to support energy efficiency projects across various sectors, including buildings, the fund provides critical financial resources to accelerate the implementation of energy-saving measures and reduce greenhouse gas emissions. Through a combination of grants, loans, and other financial incentives, the Energy Efficiency Fund enables homeowners, businesses, and municipalities to overcome financial barriers and invest in energy-efficient technologies and practices. By facilitating access to capital, the fund empowers stakeholders to undertake projects that yield long-term energy savings, enhance comfort and liveability, and contribute to environmental protection. One of the key objectives of the Energy Efficiency Fund is to promote innovation and deployment of cutting-edge technologies that improve energy performance in buildings. Whether through the adoption of advanced insulation materials, smart heating and cooling systems, or renewable energy solutions, the fund incentivizes investments that push the boundaries of energy efficiency and pave the way for a sustainable future. Moreover, the Energy Efficiency Fund serves as a catalyst for economic growth and job creation, particularly in the burgeoning clean energy sector. By stimulating demand for energy efficiency products and services, the fund creates opportunities for businesses to innovate, expand, and thrive in a rapidly evolving market. In summary, Italy's Energy Efficiency Fund embodies the country's commitment to harnessing financial mechanisms to drive sustainable development and combat climate change. By mobilising resources, fostering innovation, and empowering stakeholders, the fund lays the foundation for a greener, more prosperous future for Italy and beyond.

Green New Deal: Italy's commitment to a "Green New Deal" signifies a comprehensive and strategic approach to sustainable development. Within this framework, funding for energy efficiency renovations in buildings plays a crucial role. The Green New Deal envisions a holistic transformation, aiming to integrate environmental considerations into economic policies. The funding allocated under the Green New Deal for building renovations aligns with the broader vision of a low-carbon, resource-efficient, and socially inclusive economy. It positions Italy as a leader in sustainable development, fostering a future where energy-efficient buildings are integral to the nation's prosperity and environmental stewardship.

European Union (EU) Funding: Italy's access to European Union funding for energy efficiency projects amplifies the impact of its national initiatives. Programs such as Horizon Europe and the European Regional Development Fund (ERDF) provide additional financial resources to support Italy's endeavours in enhancing energy efficiency, including building renovations. This collaboration on the European stage not only shares the burden of funding but also promotes knowledge exchange and best practices. Italy's participation in EU funding programs underscores a collective commitment to addressing climate change and promoting sustainable development across borders.

Regional and Local Incentives: The decentralisation of incentives to regional and local levels reflects Italy's recognition of the diverse needs and priorities across its territories. Regional and local governments play a crucial role in tailoring incentives to the specific challenges and opportunities within their jurisdictions. These localised incentives ensure that the benefits of energy efficiency renovations reach all corners of the country. By acknowledging and addressing regional nuances, Italy fosters a more inclusive and adaptable approach to sustainable development, driving a comprehensive nationwide transformation in building practices.

In conclusion, Italy's multifaceted funding solutions for energy efficiency renovations in buildings showcase a holistic and ambitious strategy. By combining tax incentives, comprehensive credits, and collaboration at national and international levels, Italy aspires to lead the way in sustainable construction practices, creating a legacy of resilience, efficiency, and environmental responsibility.

4.3. Slovenia

4.3.1. Overview of Selected Financial Solutions

Energy Renovation Subsidies (ERS)

Energy renovation subsidies offered by the Slovenian government aims to make energy efficiency renovations more accessible and affordable for building owners. These subsidies target a range of activities such as:

- Development of energy performance certificates.
- energy audit reports
- implementation of energy saving measures

By offsetting a portion of the costs associated with energy renovations, these subsidies encourage homeowners, businesses, and public institutions to invest in improving the energy performance of their buildings. In addition to providing financial assistance, energy renovation subsidies contribute to raising awareness about the importance of energy efficiency and sustainable building practices. By promoting the uptake of energy renovations, Slovenia aims to reduce energy consumption, lower greenhouse gas emissions, and enhance the overall quality and comfort of buildings across the country. Energy renovation subsidies exemplify Slovenia's commitment to promoting energy efficiency and environmental sustainability, aligning with broader efforts to transition to a low-carbon economy and mitigate the impacts of climate change.

Tax Incentives: Slovenia's use of tax incentives represents a strategic approach to incentivizing energy efficiency renovations in buildings. Property owners may be eligible for tax deductions or credits for expenses related to energy-saving upgrades, such as insulation, windows, doors, and energy-efficient appliances. These tax incentives serve to reduce the financial burden associated with energy renovations and make sustainable building practices more financially attractive. By leveraging the tax system to promote energy efficiency, Slovenia encourages investment in sustainable building upgrades, stimulates market demand for energy-saving products and services, and fosters innovation in the construction sector. Tax incentives also help to create a level playing field for energy-efficient buildings, ensuring that the benefits of energy renovations are accessible to all building owners, regardless of their financial means. Slovenia's use of tax incentives reflects its commitment to promoting energy efficiency as a key pillar of sustainable development and underscores the government's efforts to create an enabling environment for sustainable building practices.

European Union Funding: Slovenia's access to European Union funding provides a valuable source of support for energy efficiency projects, including building renovations. EU programs such as the European Regional Development Fund (ERDF) and the Cohesion Fund offer financial assistance to member states to implement energy efficiency initiatives and promote sustainable development. By accessing EU funding, Slovenia can leverage additional resources to support its efforts to drive energy efficiency renovations in buildings. These funds complement national initiatives and help to scale up energy efficiency measures, accelerate the transition to a low-carbon economy, and enhance the resilience of the built environment. Slovenia's participation in EU funding programs underscores its commitment to collaboration and partnership in addressing shared environmental challenges and advancing the goals of sustainable development at both the national and European levels.

Eco Fund: The Eco Fund (Eko Sklad) is a government-funded financial institution that supports various environmental and energy efficiency projects, including those related to social housing. The Eco Fund, established in 1993, plays a pivotal role in promoting environmental protection through financial incentives, including soft loans and grants, for various environmental investment projects. Initially focused on soft loans for environmental investments, it shifted towards maintaining the real value of its assets and introduced grants in 2008. These grants are primarily funded by energy end-users' fees and the climate change fund (CO2 allowances). The fund operates through yearly plans, issuing public calls for applications. The increasing number of applications reflects its impact on tax revenues, reducing the grey economy, creating green jobs, and fostering sustainable development. Eco Fund has expanded its role to include the organisation of a free energy advisory network and addressing energy poverty by covering costs for selected households. Facing new challenges, it aims to align financial incentives with national strategies, emphasising deep energy renovations, addressing energy poverty, stimulating refurbishments in the building stock, and developing innovative financial instruments.

Public-Private Partnerships: Slovenia's promotion of public-private partnerships represents a strategic approach to financing energy efficiency renovations in buildings. By partnering with private investors and energy service companies (ESCOs), the government can mobilise additional resources and expertise to implement energy-saving measures and improve the energy performance of buildings. Public-private partnerships offer a range of benefits, including access to private capital, technical know-how, and innovative financing mechanisms such as Energy Performance Contracts (EPCs). Through these partnerships, Slovenia can overcome financial barriers, accelerate the uptake of energy efficiency renovations, and achieve greater energy savings and environmental benefits. By fostering collaboration between the public and private sectors, Slovenia's public-private partnerships contribute to the development of a vibrant and sustainable economy, creating opportunities for investment, job creation, and innovation in the sustainable construction sector.

Education and Awareness Programs: Slovenia's investment in education and awareness programs plays a critical role in promoting energy efficiency renovations in buildings. These programs provide information, training, and technical assistance to homeowners, businesses, and local communities on energy-saving measures, available funding options, and best practices for building renovations. By raising awareness and building capacity, Slovenia empowers individuals and organisations to take action to improve the energy performance of buildings and reduce their environmental impact. Education and awareness programs also help to foster a culture of sustainability, encouraging sustainable behaviour and decision-making at all levels of society. Through its investment in education and awareness programs, Slovenia demonstrates its commitment to promoting energy efficiency as a key strategy for achieving sustainable development and addressing climate change. By empowering citizens with knowledge and skills, Slovenia aims to create a more resilient and sustainable built environment for future generations.

In conclusion, Slovenia's funding solutions for energy efficiency renovations in buildings reflect a comprehensive and multi-faceted approach to promoting sustainable development and environmental stewardship. By leveraging financial incentives, accessing EU funding, promoting public-private partnerships, and investing in education and awareness, Slovenia is driving progress toward its energy efficiency goals and building a more sustainable future for all.

5. Optimal Leverage Ratio Analysis

Social housing associations play a vital role in providing affordable housing options for individuals and families with limited incomes. As the demand for energy-efficient housing continues to grow, these associations are faced with the challenge of financing and implementing energy efficiency projects to meet sustainability goals while maintaining affordability. One key factor in successfully undertaking such projects is determining the optimal leverage ratio, which balances the use of borrowed funds and equity capital to maximise returns.

This section explores the concept of the optimal leverage ratio for social housing associations in the context of energy efficiency projects. It aims to analyse various approaches to determining this ratio, examine its impact on financial risk and return on investment, and identify best practices for managing leverage to achieve both social and financial objectives. By understanding how social housing associations can strategically utilise leverage, this section contributes valuable insights into enhancing energy efficiency initiatives within the affordable housing sector.

5.1. Definition and Significance of Leverage Ratio

The leverage ratio, also known as the debt ratio or debt-to-equity ratio, is a crucial financial indicator that reflects the financial position of an enterprise by measuring the proportion of borrowed capital to total assets within the organisation (Blank, 2002). As stated by Belolipetskiy (2006), leverage refers to a long-term operating factor that can significantly influence various performance indicators. Financial managers and analysts utilise this ratio to characterise their approach towards business financing. It involves utilising borrowed funds to create financial leverage to enhance the return on invested capital. Prior to obtaining a loan or a funding source for implementing the proposed SUPER-i EE renovations, it is imperative for social housing companies' management to calculate their financial leverage to assess its effects. The calculation of the financial leverage ratio involves determining the relationship between debt and equity using the following formula:

$$Leverage\ ratio = \frac{Debt}{Debt + Equity}$$

This formula utilises values from balance sheets, considering both long-term and short-term liabilities as part of borrowed capital.

5.2. Factors Influencing Optimal Leverage

The optimal leverage ratio can be defined as the level of debt a company should use to maximise its value. It is the balance between the benefits and costs of debt financing. A higher leverage ratio can provide tax advantages and increase returns for shareholders, but it also increases the risk of financial distress and bankruptcy. On the other hand, a lower leverage ratio reduces financial risk but may limit the company's ability to take advantage of growth opportunities. The optimal leverage ratio varies across industries and depends on factors such as business risk, financial health, and market conditions. Additionally, regulatory requirements and the availability and cost of debt financing also influence the optimal leverage ratio. Therefore, companies must carefully consider these factors when determining their optimal leverage ratio to ensure financial stability and maximise shareholder value (Le Thi Huong Tram, Nguyen Thi Thanh Nga (2023)). Factors influencing optimal leverage ratio in energy efficiency projects vary depending on various factors such as the project's scope, size, and risk profile. One of the primary factors influencing the leverage ratio is the availability of external financing options. Energy efficiency projects often require significant upfront investments, and therefore, leveraging external financing sources becomes crucial for their implementation. These external financing sources can include equity investors, debt finance, government grants, and subsidies. The optimal leverage ratio is influenced by the cost of debt and equity, which can be affected by factors such as interest rates, credit rating, and the risk profile of the project. Another factor influencing the optimal leverage ratio is the project's expected cash flows, as it determines the ability to service the debt and generate returns for equity investors. Additionally, the project's expected lifespan, market conditions, and regulatory environment can also impact the optimal leverage ratio. Overall, a comprehensive assessment of these factors is necessary to determine the optimal leverage ratio for energy efficiency projects.

Cost of Debt: The cost of debt plays a significant role in determining the optimal leverage ratio for a company. This factor refers to the interest rate or the cost of borrowing funds for the company's operations. Higher interest rates lead to increased costs of debt, which can negatively impact a company's cash flow and profitability. According to (Damodaran, Aswath), companies with high levels of debt may face difficulties in meeting interest payments and may be exposed to financial distress. On the other hand, lower interest rates reduce the cost of debt, making it more affordable for companies to borrow funds. This can improve the company's financial position and increase its ability to leverage debt. Therefore, the cost of debt is an essential consideration when determining the optimal leverage ratio for a company.

Cost of Equity: Another important factor influencing the optimal leverage ratio is the cost of equity. The cost of equity represents the return required by shareholders for their investment in the company's common stock. When a company has a higher cost of equity, it may be more difficult for them to attract investors, resulting in a higher cost of capital overall. This can affect the optimal leverage ratio as a higher cost of equity may incentivize the company to rely more on debt financing to lower their overall cost of capital. However, it is important to note that increasing the proportion of debt in the capital structure also increases the financial risk of the company. Therefore, a balance must be struck between the cost of equity and the risk associated with higher leverage ratios (Olena Velyka, I. Kozlova).

Project Risk: Project risk is another important factor that influences the optimal leverage ratio. The level of risk associated with a project can impact the debt capacity of a company and therefore affect its leverage ratio. Higher levels of risk typically require a lower leverage ratio to mitigate the potential negative impact on the company's financial stability. On the other hand, projects with lower levels of risk can support a higher leverage ratio as they provide a more stable source of cash flows. Factors that contribute to project risk include market conditions, competition, regulatory environment, technological advancements, and project complexity. Evaluating and managing project risk is crucial for determining the appropriate level of leverage that a company can sustain without jeopardising its financial health. By considering project risk, companies can make informed decisions regarding their leverage ratios, which can ultimately impact their long-term financial performance and sustainability (Jae-Hun Jung, J. Jun).

Financial Flexibility: plays a significant role in determining the optimal leverage ratio for a firm. Financial flexibility refers to the ability of a company to adapt to changes in its financial circumstances and take advantage of new opportunities. It is closely related to the concept of liquidity and the firm's ability to meet its short-term obligations. According to (Le Thi Huong Tram, Nguyen Thi Thanh Nga 2023), companies with higher financial flexibility are better positioned to handle unexpected events and economic downturns, reducing the risk of financial distress. Additionally, firms with greater financial flexibility can undertake new investments and growth opportunities, which can have a positive impact on their leverage ratio. Therefore, in evaluating the optimal leverage ratio, it is essential to consider the financial flexibility of the firm.

<u>Tax Considerations</u>: Tax considerations are an important factor that influences the optimal leverage ratio for a company. Taxes can have a significant impact on a company's cash flow and profitability, and therefore, it is crucial to consider them when determining the appropriate level of leverage. Interest payments on debt are tax-deductible, meaning that companies can reduce their taxable income by deducting the interest expenses from their earnings. This tax shield effect can provide a significant advantage to companies that have a higher proportion of debt in their capital structure (Le Thi Huong Tram, Nguyen Thi Thanh Nga). However, it is important to note that the tax benefit of debt is subject to certain limitations and can vary depending on the tax laws and regulations in the company's jurisdiction (G. Chauhan). Therefore, companies need to carefully evaluate their tax situation and consider any potential changes in tax regulations when determining their optimal leverage ratio.

5.3. Optimal leverage ratio using the WACC method.

The main methodology to classify the leverage ratios is Weighted average cost of capital. The Weighted Average Cost of Capital (WACC) is a financial metric that represents the average cost of a company's debt and equity capital. The optimal leverage is the level of debt that minimises the WACC, thus maximising the firm's value. The WACC is calculated using the following formula:

$$WACC = \frac{Equity}{Equity + Debt} * R_e + \frac{Debt}{Equity + Debt} * R_d * (1 - T_c)$$

Where R_e is the cost of equity, R_d is the cost of debt, and T_c is the corporate tax rate.

To find the optimal leverage, we minimise the WACC with respect to the debt ratio ($\frac{Debt}{Equity+Debt}$). The optimal leverage point occurs when the marginal benefit of adding more debt equals the marginal cost. In other words, the optimal debt ratio that minimises the WACC.

5.4. Risk Assessment

Assessing the value generation and risks related to an energy efficiency (EE) project can go along with significant transaction costs. Bearing such costs may or may not be justified for Financial Intermediaries (FI), depending on the financing amount and financing approach under consideration. Typically, the value generation from and risks of a specific project are assessed only if investment amounts are substantial, or in the case of non-recourse or project financing. In contrast, financing decisions for EE projects, which usually go along with relatively small investment amounts, tend to be based on the repayment capacity of the borrower only, i.e. without taking the values and risks of the specific project into consideration. For such smaller projects, the relevance of EE values and risks for the repayment of the loan is considered too small relative to the transaction costs of assessing them.

The assessment of an EE project’s values and risks can be worth its cost even for smaller investment amounts under several circumstances. These include cases in which the share of energy costs in a company’s turnover is significant; cases in which energy cost savings could be used as collateral; or cases in which the borrower is an ESCO. Further, FIs that can identify the environmental impact of financed projects, including energy and CO2 emissions savings, can benefit from growing sources of green finance, and hence in many cases reduce their capital costs. Successful energy efficiency investments reduce energy consumption per unit of output and hence decrease the share of energy costs in a company’s turnover. Besides the resulting positive impact on a company's cash flows, the reduction of energy costs can also imply a lower exposure to volatile energy prices and hence a stabilisation of a company's profits.

Other benefits that often go along with EE investments, such as decreased maintenance costs, higher productivity, or higher asset values, can further amplify an energy efficiency project's positive impact on a company's financials. Such value generation from an EE project, i.e. improved cash flows and lower volatility, can result in a lower risk of default and hence there is an argument that lenders should account for these values in credit risk assessment, eventually implying more attractive financing terms for borrowers (Blyth and Savage (2011)). However, to justify the transaction costs which a financial intermediary face when appraising the impact of an EE project on a borrower's cash flows, the presumed impact of the EE project on the borrower's risk of default must be sufficiently significant. This significance may be given under the following circumstances:

- High degree of energy cost uncertainty: For energy efficiency to reduce a company's credit risk, its energy costs must be both risky and substantial in relation to its profit.
- High energy-saving potential of the project: The higher the energy-savings potential, the greater the risk reduction.
- Low degree of cost pass-through to customers: If companies can pass through the variations in energy costs to their customers by varying their product prices, then energy efficiency projects will not reduce credit default risk.

5.5. Interpretation of results on leverage ratio

The economic and financial interpretations of the optimal leverage ratio for Italy, Denmark, and Slovenia based on Table 1, is based on the Weighted Average Cost of Capital (WACC) and its relation to the economic environment and financial performance of each country. The leverage ratio has been simulated for the next 25 years using *Nasdaq*[1], *LSEG*[2] *and Saint Louis FED*[3] *datasets* as inputs for the inflation rate, interest rate and corporate tax rate.

Italy: The optimal leverage ratio fluctuates over the years but generally remains around 0.7 to 0.795, based on the median values. The higher comparative optimal leverage ratio suggests that Italy can benefit from debt financing to a certain extent, this suggests that social housing companies may find an optimal balance between debt and equity financing of energy efficiency projects within this range. This high leverage ratio indicates that debt plays a significant role in the capital structure of Italian firms possibly due to:

Lower borrowing Costs. During periods of low interest rates, companies may find it advantageous to use debt financing to fund investments and expansion projects.
Tax Benefits. Italy's corporate tax laws and regulations regarding debt interest deductibility may incentivize social housing companies to use debt financing to fund EE renovation projects and benefit from tax shields, thereby lowering their effective tax rates and increasing profitability.
Industry Composition. Social housing companies in Italy may inherently require higher levels of leverage due to the capital-intensive nature of their operations.

Denmark: The optimal leverage ratio ranges from 0.699 to 0.868, based on the median values. Denmark's higher leverage ratio compared to Italy suggests that Danish companies may have easier access to debt financing and can efficiently utilise debt in their capital structure. This higher optimal leverage ratio in Denmark can be explained by several factors such as:

Financial Market: Denmark's well-developed financial markets and robust banking system may provide social housing companies with easier access to debt financing at competitive rates. This facilitates leveraging for growth and investment opportunities in energy efficiency renovation projects in the social housing sector.
Investor Preferences: Danish investors may have a higher risk tolerance and may view debt financing as a favourable strategy, especially if social housing companies can demonstrate efficient use of leverage to generate returns exceeding the cost of debt (National Building Fund).
Regulatory Environment: Denmark's regulatory framework is conducive to debt financing, with policies that support capital market development and facilitate corporate borrowing.

Slovenia: The optimal leverage ratio ranges from 0.592 to 0.728, based on the median values. Slovenia's lower leverage ratio compared to Italy and Denmark suggests a more conservative approach to debt financing. Slovenian companies may prefer equity financing or have limited access to debt markets due to higher borrowing costs or risk perceptions. Several factors contribute to this conservative stance:

Risk Aversion: Slovenian social housing companies may exhibit a lower risk appetite compared to their counterparts in Italy and Denmark. This could stem from historical experiences, risk aversion among investors, or cautious financial management practices.
Capital Market Constraints: Slovenia has less developed capital markets and banking infrastructure compared to Italy and Denmark, resulting in limited access to debt financing or higher borrowing costs for social housing companies.
Government Policies[4]: Government policies and regulations in Slovenia may discourage excessive leverage or speculative financial practices, prioritising financial stability and prudent risk management.

United Kingdom (UK): The median optimal leverage ratio for the UK over the period from 2024 to 2043 is 0.800. For energy efficiency renovation projects in social housing, this suggests that UK investors should aim for a leverage ratio around 0.800. With a slightly higher reliance on debt financing, investors can leverage funds to implement these projects efficiently, potentially yielding higher returns while managing financial risk.

Spain: The median optimal leverage ratio for Spain over the same period is 0.704. Spanish investors targeting energy efficiency renovation projects should consider maintaining a leverage ratio around 0.704. This indicates a preference for a slightly lower proportion of debt compared to the UK, potentially reflecting different market dynamics and risk preferences. Investors should balance leveraging with financial stability.

Belgium: Belgium's median optimal leverage ratio over the period is 0.711. Investors in energy efficiency renovation projects in Belgian social housing should target a leverage ratio around 0.711. Like Spain, Belgium's optimal leverage ratio suggests a balanced approach to financing, with a slightly lower reliance on debt compared to the UK. This balance helps manage financial risk while facilitating project implementation.

In summary, a country with a higher optimal leverage ratio may indicate a more developed financial market with lower borrowing costs, allowing companies to leverage more for growth and investment. Conversely, a lower optimal leverage ratio may suggest tighter credit conditions, higher borrowing costs, or a preference for equity financing due to lower risk tolerance or regulatory constraints. Overall, these optimal leverage ratios provide insights into each country's financial environment, including access to capital, risk preferences, and market conditions, which can influence investment decisions and corporate strategies.

	Five year median optimal leverage ratio - WACC method					
Year	**Italy**	**Denmark**	**Slovenia**	**UK**	**Spain**	**Belgium**
(2024-2028)	0.759	0.807	0.728	0.820	0.730	0.731
(2029-2033)	0.795	0.814	0.714	0.816	0.711	0.724
(2034-2038)	0.702	0.699	0.592	0.721	0.621	0.634
(2039-2043)	0.700	0.770	0.605	0.747	0.645	0.658
(2024-2043)	0.739	0.796	0.694	0.800	0.704	0.711

Table 1: Five years median optimal leverage ratio using the Weight Average Cost of Capital method.

6. Technical Considerations

Tackling fuel poverty and moving to a net zero built environment are priorities across Europe, driving renovation and refurbishment of all housing, with governments often particularly active in the improvement of social housing. How each MS designs the relevant policy instruments and which interventions are included - will depend on the climate, existing housing stock and national finances. Under the Energy Performance of Buildings Directive[5] (EPBD), EU MS are required to set minimum energy requirements in national building regulations with a view to achieving cost-optimal levels. In determining these targets, MSs will typically define the technology mix relevant to their transition to a net zero built environment. Below we present the EPBD targets for the 3 pipeline countries, and discuss the available, cost -optimal technologies that will allow them to reach those targets.

6.1. Italy:

Italy has specified minimum U-values for all domestic and non-domestic buildings, below[6] - these come into force during renovations of a prescribed scale. There are also a number of qualitative requirements that relate to cooling, such as that: In case of new windows (except on the north façade), the total solar transmission factor shall be lower than 0.35; and [users must] verify the techno-economic feasibility to adopt technical solutions (cool roof, ventilated roof, green roof).

Elements / Components		Validity period	Thermal transmittance U [W/m²K](including thermal bridges)				
			Climatic Zone				
			A and B	C	D	E	F
Envelope	walls	From 2015	0.45	0.38	0.34	0.30	0.28
		From 2019/2021	0.43	0.34	0.29	0.26	0.24
Envelope	roofs	From 2015	0.38	0.36	0.30	0.25	0.23
		From 2019/2021	0.35	0.33	0.26	0.22	0.20
Envelope	floors	From 2015	0.46	0.40	0.32	0.30	0.28
		From 2019/2021	0.4	0.38	0.29	0.26	0.24
Doors, windows and shutter boxes		From 2015	3.20	2.40	2.00	1.80	1.50
		From 2019/2021	3.00	2.20	1.80	1.40	1.10
Indoor partitions		From 2015	0.80	0.80	0.80	0.80	0.80
		From 2019/2021	0.80	0.80	0.80	0.80	0.80

Table 2: Italy - Minimum U-values for all domestic and non-domestic buildings.

Promoting knowledge of the national building stock is also a key plank of the Italian policy suite, for example:

Minimum Environmental Criteria (CAM) for constructions provide that, for the renovation/maintenance projects of existing buildings, an energy audit must be conducted to identify the energy performance of the building and the actions to be taken for the reduction of its energy needs.

also

[under] first-level major renovation interventions, projects must ensure that the overall energy needs of the building are met by renewable energy systems or with alternative high efficiency systems.

And the government has provided a modelling tool, building on EC work, which allows the operators of existing buildings to identify the minimum cost solutions to achieve the energy saving objectives. EPCs have also been standardised and made more intuitive. The Italian climatic zones and their temperature profiles are discussed in D3.1.

6.2. Denmark

For existing buildings in Denmark, similarly to Italy, the fabric standards below must be met following replacement of components and/or major renovations - measures must be economically and technically feasible - they must have a simple payback time of less than 75% of their expected lifetime.

All existing buildings	Changed use and extensions	Single component requirements for new / replaced parts	Holiday homes	Minimum requirements*
U-value requirements [W/m²K]				
External walls and basement walls towards ground	0.18	0.15	0.25	0.30
Slab on ground, etc.	0.10	0.10	0.15	0.20
Loft and roof constructions	0.12	0.12	0.15	0.20
Windows	-	1.80 (doors)	1.80	-
Roof windows	-	-	1.80	-
Thermal bridges [W/(m K)]				
Foundations	0.12	0.12	0.15	0.40/0.20
Joints between windows and walls	0.03	0.03	0.03	0.06
Joint between roof structure and windows in the roof	0.10	0.10	0,10	0.20
Minimum energy gain [kWh/m².year]				
Facade windows	-17	-17	-	-17
Roof windows	0	0	-	0

Table 3: Denmark - Minimum U-value requirements for replacement or major renovations.

6.3. Slovenia

In Slovenia, existing buildings must have all their components brought up to the 2017 standards (in the case of major upgrades), or only the individual component in the case of more minor works. Whether the more stringent NZEB values will come to apply to existing buildings is currently under discussion.

Minimum requirements for U-value of the envelope	Status 2017 (as in current PURES 2010)	Proposed new U-values max. (NZEB)
Walls	0.28 $W/m^2.K$	0.20 $W/m^2.K$
floors between flats	0.90 $W/m^2.K$	0.90 $W/m^2.K$
flat roofs	0.20 $W/m^2.K$	0.18 $W/m^2.K$
Windows	1.3 $W/m^2.K$	1.0 $W/m^2.K$

Table 4: Slovenia - Minimum requirements for U-value of the envelope.

6.4. Building Renovation Technologies

Here, the technological means of meeting these targets are discussed. In this analysis, we make use of the quantitative analysis associated with the UKG Cost Optimal report[7]; among other data, these give the most cost-effective means of meeting particular thermal efficiency targets.

Walls:

As above, many MSs mandate thermal efficiency values for existing building envelopes, typically these regulations apply at the point the building is renovated. From the table below, meeting most of the targets above is likely to require a fully filled cavity and additional external/internal insulation, in most cases (particularly in Denmark) the buildings are likely to include some cavity insulation already.

Fabric - Cavity Walls	**Cavity Wall U-value (W/m²K)**	**Insulation**
Base case (for information)	1.5	None – 50mm uninsulated cavity
Option 1	0.55	Fully filled (50mm) cavity
Option 2	0.24	Fully filled cavity and 50mm internal insulation
Option 3	0.18	Fully filled cavity and 80mm internal insulation
Option 4	0.22	Fully filled cavity and 100mm external insulation
Option 5	0.14	Fully filled cavity and 200mm external insulation
Option 6	0.32	50mm internal insulation (unfilled cavity)
Option 7	0.22	80mm internal insulation (unfilled cavity)

Fabric – Solid Walls	**Solid Wall U-value (W/m²K)**	**Insulation**
Base case (for information)	1.7	None – uninsulated solid wall, 225mm (9inch) wall
Option 1	0.30	50mm internal insulation
Option 2	0.21	80mm internal insulation
Option 3	0.30	100mm external insulation
Option 4	0.17	200mm external insulation

Table 5: Typical U-values achieved through improvements to existing exterior walls.

Other technologies for insulating exterior walls include green walls, which can be planted vertically with shrubs, flowers, and grasses in soil or using hydroponics - these have the benefits of improving air quality and biodiversity locally as well as improving thermal performance. As these will not reduce space heating demand as much as dedicated insulation panels, the case for green walls may need to be made on a more comprehensive basis than energy savings alone.

Figure 1: Green wall at Musée du Quai Branly.

Roofs:

Insulating roofs is typically among the most cost-effective retrofit options for existing buildings, particularly houses and low-rise blocks. Achieving the targets prescribed above is likely achievable by adding mineral wool between and above the joists.

Fabric – Roof	Roof U-value (W/m²K)	Insulation
Base case (for information)	0.68	50mm mineral wool insulation
Option 1	0.29	100mm mineral wool insulation quilt between joists PLUS 50mm above joists
Option 2	0.13	100mm mineral wool insulation quilt between joists PLUS 200mm above joists
Option 3	0.11	100mm mineral wool insulation quilt between joists PLUS 250mm above joists

Table 6: Roof U-values

Windows:

Insulating windows to high U-values typically becomes increasingly expensive as the requirement is increased, and often other considerations around noise and mechanism must also be considered. As such, the window requirements laid out above are typically met by standard modern double glazed UPVC windows.

Fabric – Windows	**Window U-value (W/m²K)**	**Type**
Base case (for information)	3.1	Double glazed
Option 1	1.6	Double glazed U-PVC windows
Option 2	1.4	Double glazed U-PVC windows
Option 3	1.2	Double glazed U-PVC windows
Option 4	0.9	Triple glazed U-PVC windows

Table 7: Windows U-values.

6.5. Materials

Across Europe, the best predictor of building stock thermal efficiency is age; the individual picture will vary by MS, but in nearly all cases the EPC ratings of buildings will improve for more recently built stock. This is largely explained by improvements in the materials used. Building standards have driven much of this improvement, sometimes through performance standards (as in the EPBD submissions above, where minimum U-values are mandated) and sometimes through the technologies themselves, e.g. where the UK required all new buildings to include cavity wall insulation, accelerating the market for that product.

From 2030, onwards, new buildings must have no emissions from fossil fuels by 2030 under the Nearly Zero Energy Buildings plan, though with new build rates around 1-2% of total stock across Europe, and demolition rates lower, in 2050 - the date of the EU climate neutral target - most of the current build stock will still be in use, with many of these built pre-1970, the date of the earliest energy use policies in buildings in Europe. Therefore, the majority of the energy for heat in homes must be tackled by retrofit and renovation.

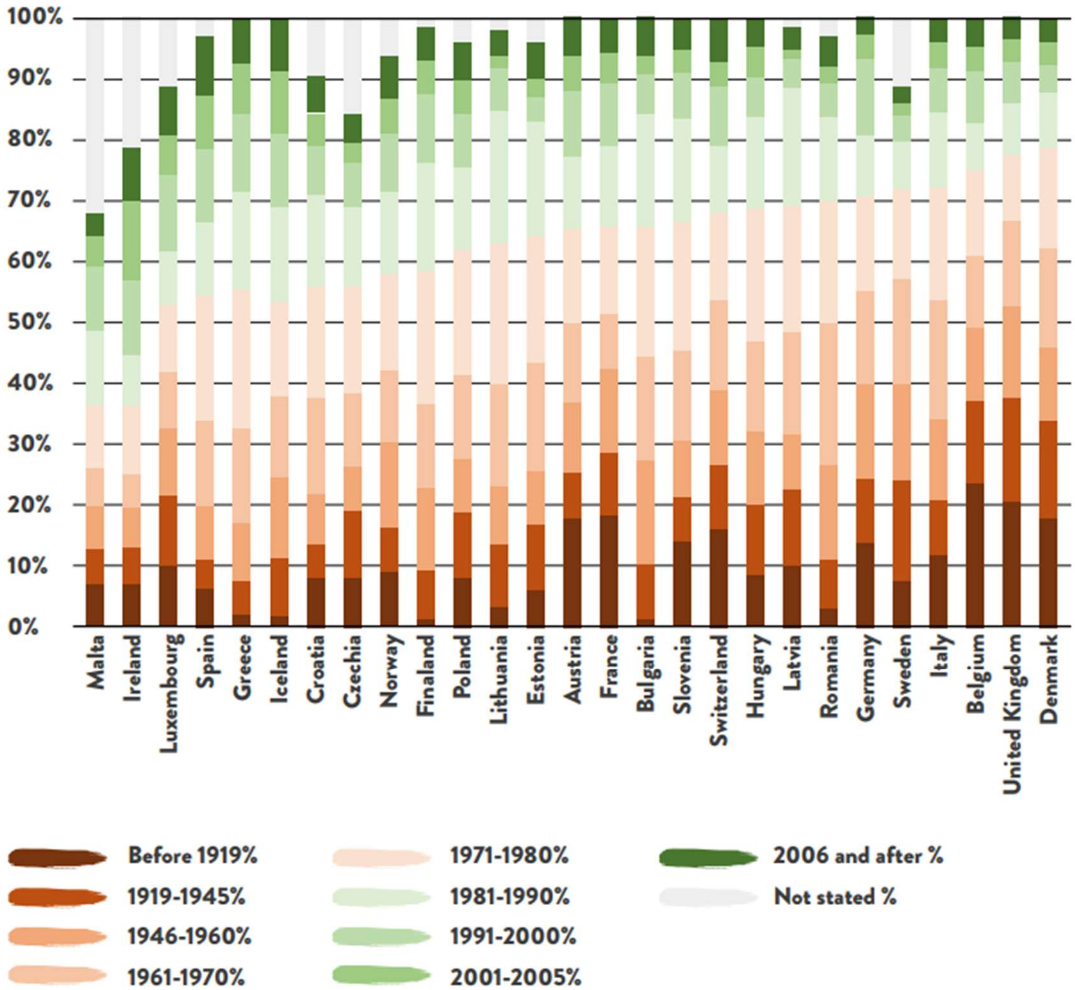

Figure 2: EU MS Total Dwellings by age, from The State of Housing in Europe (2023), source Census Hub (year of reference 2011).[8]

EU MS Total Dwellings by age, from The State of Housing in Europe (2023), source Census Hub (year of reference 2011)

6.6. Energy Efficiency Measures

Heating Systems:

In addition to improving the thermal efficiency of the building fabric, there are cost-effective interventions that can reduce demand for heating and increase the efficiency of their delivery. For example, the Danish pipeline buildings - indeed most homes in Denmark - are connected to district heating networks, and the Danish pipeline buildings propose installing heat recovery mechanisms to decrease the flow return temperature. In units where individual gas heaters are used, such as in Slovenia, measures under EPBD above mandate minimum boiler efficiencies, typically around 90% requiring condensing flues.

Greater primary energy savings can be made by switching to heat pumps - which generate between 2 and 4 units of heat for each unit of electricity. There are however currently few such explicit mandates across Europe, though a range of capital and fuel subsidies are available across MSs. No SUPER-i participants propose installing heat pumps, and domestic central heating systems can be difficult to switch to heat pumps where the required flow temperatures are over 60C.

Passive measures

The energy use of buildings can be addressed by passive measures, design and operational principles which take into consideration factors such as the:

- Location
- Landscape
- Orientation
- Shading
- Materials & Insulation
- Internal layout, and the location of doors and windows

Passive measures are ideally considered early in the design process, and most options are difficult to consider for retrofit and some principles, such as taking advantage of the waste heat of ICT systems, do not apply in social housing. However, some technologies, such as green roofs can assist with heating and cooling and are recommended above.

Education of residents can also assist in the energy use of shared buildings, though again in social housing this may require specific considerations.

6.7. Integration of Smart Technologies

On-site Generation

Some MSs EPBD regulations require review of the feasibility of fitting PV and other low-carbon energy and energy efficiency measures. Social housing blocks are often ideal candidates for on-site generation; their electrical demand is stable, and the HA can engage with developers. The location, orientation and surroundings of the buildings, and the ability to site racks on their roofs, will all need to be considered on a case-by-case basis. Novel technologies, such as PV windows, are unlikely to be cost competitive with rooftop panels.

CHP engines are also often included in large social housing developments, providing heat and electricity (typically from gas), though as electricity grids decarbonise the cost and emissions associated with CHP fall. Other on-site cogeneration options are typically marginal, though on-site biomass or anaerobic digestion may be relevant in rare cases.

Heat pumps for DSM

Social housing developments are often also ideal consumers for heat pump installations, as the Housing Association can act as a guarantor of offtake and can have the expertise to engage with providers and installers, such as ESCOs. In addition to reducing the overall primary energy demand for heating, heat pumps can also allow users to move their electrical demand diurnally, particularly when used in tandem with dedicated thermal storage. This allows residents to respond to dynamic variable time-of-use tariffs, and so reduce their energy bills. In small apartments, high-density energy storage, such as phase-change materials (PCMs), may be required. Heat pumps with demand flexibility may also be able to participate in network balancing services so further reducing their energy costs, though implementation is likely to require a market for domestic demand aggregator, and the services are likely to become oversubscribed very quickly.

7. Environmental Impact Assessment

Globally, the construction sector and buildings account for 35% of final energy consumption and 38% of global energy-related carbon dioxide (CO2) emissions[9]. In the European Union, addressing the environmental impact of building renovations is a priority under the European Green Deal[10]. The EU has set ambitious targets to reduce 40% of greenhouse gas emissions and improve energy efficiency in buildings by 32.5% in buildings by 2030. As a result, the environmental assessment for housing renovation plays a crucial role in complying with the European Green Deal, enhancing the funding options available and supporting the European renovation wave[11]. As part of this initiative, the EU's renovation wave aims to at least double the annual energy renovation rate of residential and non-residential buildings. This wave is designed to green the buildings, create jobs, and improve lives, aligning with the broader goal of achieving climate neutrality.

7.1. Environmental Considerations

The regulatory framework and standards for the environmental impact of building renovations are designed to address several critical areas:

Embodied Carbon:

Embodied carbon refers to the carbon dioxide emitted during the manufacture, transport, and construction of building materials, as well as the end-of-life phase. Reducing embodied carbon is essential for minimising the overall carbon footprint of renovation projects. Standards and regulations often encourage the use of materials with lower embodied carbon, such as recycled materials or those requiring less energy-intensive production processes.

Energy Efficiency:

Energy efficiency is a key component of sustainable building renovations. Regulations typically focus on improving the thermal performance of buildings to reduce the need for heating and cooling, thereby lowering energy consumption and associated greenhouse gas emissions. This can involve upgrading insulation, installing energy-efficient windows, and incorporating advanced heating, ventilation, and air conditioning (HVAC) systems.

Waste Reduction:

Building renovations can generate significant amounts of waste. Standards and regulations promote waste reduction through the reuse and recycling of materials, as well as the responsible disposal of waste that cannot be reused or recycled. This approach helps to minimise the environmental impact of waste generated during renovation projects.

Use of Sustainable Materials:

The choice of materials is crucial in building renovations. Regulations often encourage or mandate the use of sustainable materials that have a lower environmental impact. This can include materials that are sustainably sourced, have a high recycled content, or are more durable and require less frequent replacement.

Water Efficiency:

Water efficiency measures are increasingly being incorporated into building renovation standards, focusing on reducing water consumption through efficient plumbing fixtures, rainwater harvesting systems, and water-efficient landscaping.

Indoor Environmental Quality:

Ensuring good indoor environmental quality is important for the health and well-being of building occupants. Regulations may include requirements for ventilation, low-emission materials, and natural lighting to create healthier indoor environments.

Integration of Renewable Energy:

To further reduce the environmental impact of buildings, regulations may encourage or require the integration of renewable energy sources, such as solar panels or geothermal heating systems, into renovation projects.

These standards are not only aimed at reducing the environmental impact of building renovations but also at promoting health, comfort, and well-being for occupants. They are part of a broader effort to achieve sustainability in the built environment, in line with global initiatives such as the Paris Agreement[12] and the United Nations Sustainable Development Goals[13]. By adhering to these standards, the construction industry can play a significant role in mitigating climate change and promoting a more sustainable future. These environmental considerations have been considered to define the KPIs presented in deliverable 3.2 to create a valuable framework to evaluate the environmental impact of the different pilots before renovation and after the renovation phases.

7.2. Green Building Standards

In Europe, several green building certifications are recognized for their commitment to sustainability and environmental impact. Some of the most important green building certifications in Europe include:

LEED (Leadership in Energy and Environmental Design): A globally recognized certification system that assesses the sustainability of buildings based on a rating system. Points are awarded for meeting standards related to carbon, energy, water, waste, transportation, materials, health, and indoor environmental quality.

WELL Building Standard: An international certification program that focuses on the impact of green buildings on human health and well-being. It is based on 10 principles, including air, water, nourishment, light, movement, thermal comfort, sound, materials, mind, and community. With a WELL certificate, you can show stakeholders, investors and users what have been done to improve the health of the building.

BREEAM (Building Research Establishment Environmental Assessment Method): An international sustainability standard that assesses buildings in categories such as in-use, building, and new construction & renovation. It targets areas such as air, water, health, waste, and materials.

NZEB (Nearly Zero Emissions-Building) & ZEB (Zero Emissions-Building): A nearly zero emissions building is characterised by its high performance, with most of its energy needs being obtained by renewable sources. These sources may include on-site or nearby generated energy. The Energy Performance of Building Directive (EPBD) requires that EU countries had ensure that all new buildings were NZEB by

Living Building Challenge: A certification program that aims for buildings to have a regenerative impact on the environment. It focuses on seven performance areas: site, water, energy, health and happiness, materials, equity, and beauty. It is based on the actual performance of the building.

These certifications are part of Europe's broader efforts to address the environmental impact of the built environment and improve their energy efficiency. Moreover, they are aligned with global sustainability initiatives such as the EU Green Deal and the Paris Agreement.

7.3. Sustainable Construction Practices

Sustainable construction practices in Europe for residential buildings are gaining a critical relevance due to the region's focus on climate and circular economy ambitions. The European Union has implemented the Green Buildings Pact[14], which aims to create more climate-friendly buildings by improving energy efficiency and reducing greenhouse gas emissions. Key initiatives and policies include the EU Green Deal, the Energy Performance of Buildings Directive, and the Renovation Wave, which seeks to double the rate of building renovations by 2030. To achieve these goals, various sustainable construction practices are being emphasised, such as:

Energy Efficiency: Efforts to improve the energy efficiency of residential buildings through measures like better insulation, energy-efficient heating and cooling systems, and the use of renewable energy sources.

Circular Economy Principles: Promoting circularity in construction and demolition waste, extending product lifetimes, reducing material losses, and recirculating materials to minimise environmental impacts and mitigate climate change.

Renewable Energy Integration: Encouraging the integration of renewable energy sources such as solar power and geothermal energy into residential building designs.

Sustainable Materials: Emphasising the use of sustainable materials that are produced using environmentally friendly processes and designed to have a minimal impact on the environment.

Life Cycle Assessment: Increasing focus on life cycle assessments to analyse the environmental impact of residential buildings throughout their entire life cycle, from construction to demolition. This evaluation methodology has been further detailed due to its importance to assess environmental impacts.

These actions show that more people are realising how important it is to use sustainable building methods to help fight climate change and take care of the environment in Europe. They have been taken into consideration along with literature review on Life Cycle Assessment (LCA) on the development of KPIs (Key Performance Indicators) defined within D3.2. They aim to create an accessible framework to evaluate the impact of residential renovations on use stage for any EU country due to their flexibility on the data gathering which can be adapted to different legislation strategies.

7.4. Carbon Footprint Reduction Strategies

The concept of carbon footprint in the construction sector should be defined as the total CO2 emissions through land clearance and consumption of energy, fuels, building materials (cement, steel, aluminium, etc.), transportation and other services. Two terms should be introduced here for better understanding:

- *Embodied Carbon:* it refers to all greenhouse gas (GHG) emissions linked with the extraction and manufacture of a product or delivery of a service (LCA phases A1-A3). They are measured in tonnes or kilograms of carbon dioxide (CO2) equivalent (e). In the context of buildings, embodied carbon includes emissions associated with the extraction and supply of raw materials, their transportation to the manufacturing plant and their manufacturing and fabrication into building materials and products. This term serves as a useful metric for quantifying the environmental impact of products and services and is of particular importance in the context of building construction, where the embodied carbon of building materials can be a significant contributor to the overall carbon footprint of a building. Environmental Product Declarations (EPDs) (EN 15804[15]) play a crucial role in assessing and disclosing this embodied carbon. An EPD serves as a standardised summary report of a product's life cycle analysis, providing a detailed overview of its environmental impact. In the building industry, EPDs are widely recognized as a tool for disclosing embodied carbon.

- *Operational Carbon*: also known as OPEX, refers to the carbon emissions released during the ongoing operation and maintenance of a building over its lifetime, including energy consumption for lighting, power, heating, and other functions. Efforts to reduce operational carbon have been successful in leading projects aiming for net-zero energy use. As operational efficiencies improve and operational carbon decreases due to energy-saving measures in buildings, embodied carbon becomes a more significant proportion of total carbon emissions.

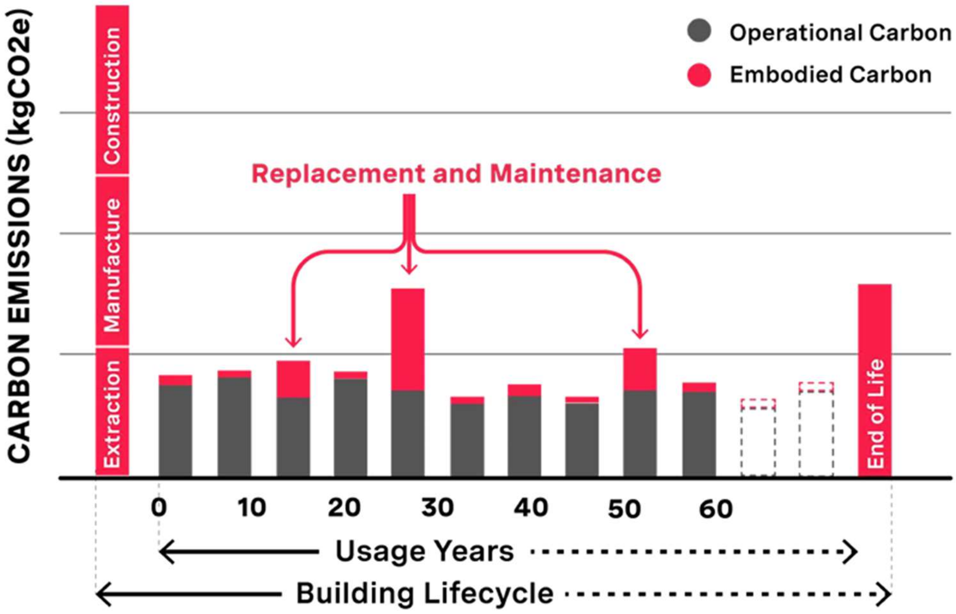

Figure 3: Embodied Carbon vs Operational Carbon. [16]

Effective reduction of carbon emissions during residential building renovation requires builders to target key material categories such as concrete, insulation, cladding, and interior surfaces, which account for over 70% of the total emissions of new home construction. Employing strategies such as designing energy-efficient buildings, using recycled materials, conducting life cycle assessments, and embracing circular economy principles can also contribute to reducing the carbon footprint of construction. Moreover, integrating eco-friendly and recycled building materials, implementing energy-efficient design, and adopting innovative construction practices like prefabrication and modular construction can further minimise the environmental impact and reduce carbon emissions. To achieve zero-carbon buildings, stakeholders should consider a comprehensive approach that encompasses the aforementioned strategies. It will demonstrate their commitment to sustainability while contributing to global efforts to mitigate climate change. The International Energy Agency (IEA) provides valuable insights into the different aspects that can be considered in this regard.

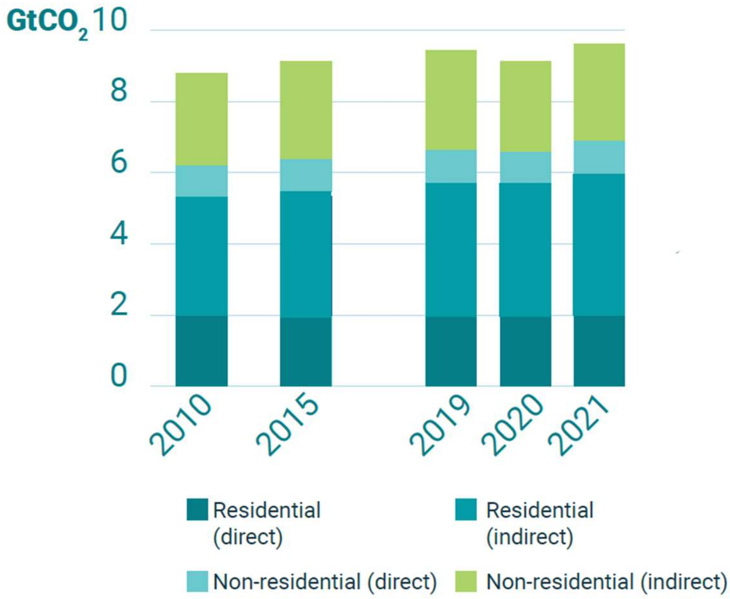

Figure 4: CO2 emissions in buildings 2010-2021. [17]

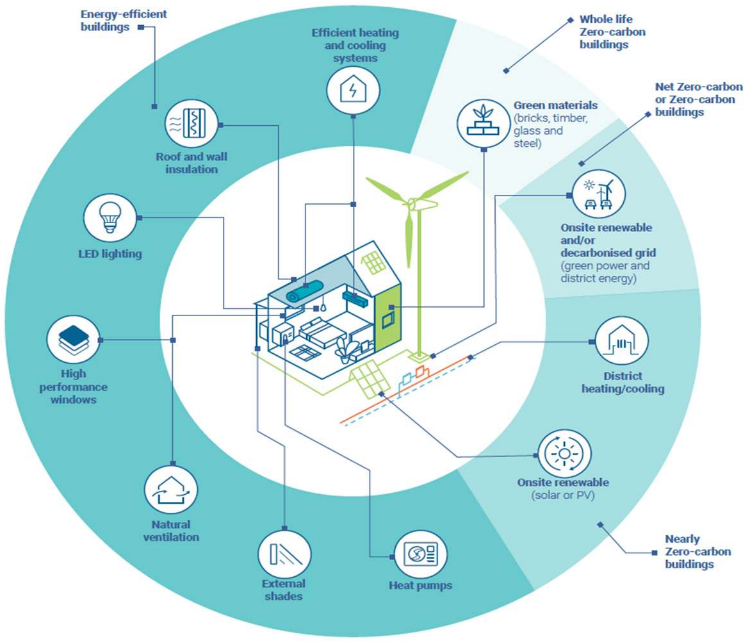

Figure 5: Different levels of Zero-Carbon in buildings [18]

8. Life Cycle Assessment (LCA) and Social Life Cycle Assessment (SLCA)

8.1. LCA/SLCA Methodology

Life Cycle Assessment (LCA) and Social Life Cycle Assessment (SLCA) methodologies are essential tools for assessing the environmental and social impacts of products or services over their lifetimes. The LCA methodology is commonly employed for assessing the environmental impacts of a product or service over the entire period of its life. In this case it will be focused on the LCA of a building. The UNE-EN 15643 standard, titled "Sustainability of construction works - Framework for assessment of buildings and civil engineering works," outlines the requirements and procedures for evaluating the environmental, social, and economic impacts of buildings. This framework applies to all construction projects throughout their entire life cycle, offering quantifiable indicators. Its aim is to gauge the impacts generated by assets and aid stakeholders in decision-making processes, particularly concerning energy efficiency measures, materials selection, and building design. The goal is to provide a consistent reference point for communicating and illustrating the analysed aspects, be they environmental, economic, or social. LCA is an iterative methodology, which means that it involves refining the process as you go along. It is possible that the initial analysis may reveal that the results of the assessment or interpretation require you to revise your goal and scope. Sometimes. Incorporating LCA into construction practices not only helps in reducing environmental impact but also leads to cost savings, improved stakeholder engagement, regulatory compliance, and overall sustainability in the built environment.

According to CEN TC350 standards[19][20], the following diagram (Fig 21) comprises all the scope of the LCA to assess the impacts of buildings life cycle (Fig 22), on the other hand Figure 2 shows all the LCA stages and boundaries for buildings refurbishment.

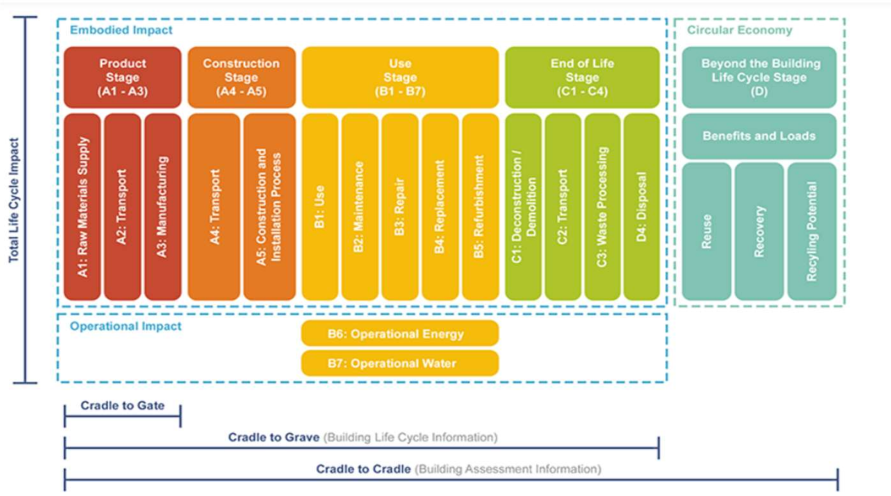

Figure 6: The scope of Life Cycle Assessment to assess the impacts of building life cycle.

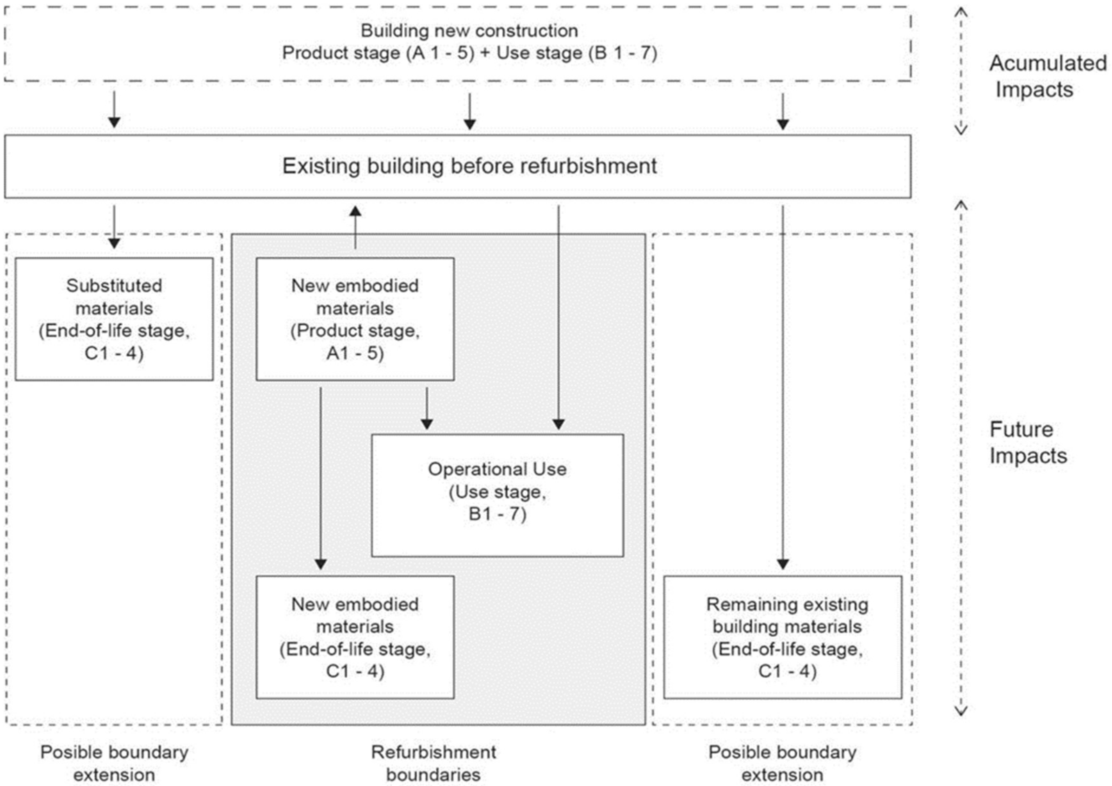

Figure 7: Life Cycle Assessment (LCA) stages and boundaries for buildings´ renovation. [21]

The standards for LCA methodology, describe four main phases of an LCA:

1. Goal and scope analysis.
2. Inventory analysis.
3. Impact assessment.
4. Interpretation.

SLCA expands on LCA by including the social benefits and drawbacks of the refurbishment and renovation social housing strategies. It helps measure and manage social risks, enabling the assessment, identification, prioritisation, mitigation, targeting, and reporting of social issues in line with international best practices. It also allows for the measurement of positive changes resulting from interventions through a social handprint study, aiding in progress tracking and reputation enhancement. The same phases described under LCA are applicable to SLCA. The International Standards Organisation (ISO) is developing a standard for Social Life Cycle Assessment (ISO 14075) to globally standardise SLCA methodologies and promote best practices in assessing and managing social issues. An SLCA methodology has been developed for the SUPER-i project to evaluate the social impacts that affect the residents in pilot locations (as described inD3.2). This methodology has been created based on literature review and using previous experience in other projects that analyse social impact. It considers the situation before renovation (baseline) and after it, during the use phase. The goal is to help make better decisions during the design phase by analysing the baseline, identifying areas of improvement, as well as, evaluating the impact after renovation.

8.2. Data Collection and Analysis

To define the data gathered, the phases of the LCA approach should be used for both assessments (LCA/SLCA).

1. *Identifying goal and scope:* Defining what is the goal of the assessment and based on it identifying what you want to assess. For the LCA assessment this included deciding on the life cycle stages: production, construction, use and end of life, and for SLCA what social aspects would you like to evaluate.
2. *Gather Data:* To make informed decisions, sufficient and accurate information on the materials, quantities, energy consumption, and other relevant parameters must be available. In this regard, ongoing monitoring and regular data collection are required to track the progress of refurbishments and to identify potential improvements. Organising the collected data into an inventory is crucial for quantifying the environmental impacts associated. A set of defined KPI ́s has been defined for analysis purposes within the project, the data collection will be done through surveys to stakeholders and residents. Alternative methods of data collection have been specified under each dedicated KPI, where the data can be collected from Energy Performance Certificates (EPC), public databases and other accessible sources.
3. *Impact assessment:* The environmental impacts of the renovation will be assessed using the KPIs created for this purpose, although a LCA analysis on production, use and end of life phase is recommended for more in-depth analysis.
4. *Interpretation:* Analyse the results to draw conclusions and make recommendations. This step involves evaluating the overall environmental performance of the renovation and social aspects and identifying opportunities for improvement.

8.3. Integration of LCA/SLCA in Decision Making

Integrating social and environmental LCAs provides a comprehensive understanding of the impact on both the environment and society. This integration enables the development of socially ethical and sustainable building renovations that add value to investment decisions and meet or exceed customer expectations.

9. Environmental Regulations per Demo Case

9.1. ITALY

Environmental regulations for housing building renovation in Italy have been implemented to reduce energy consumption, greenhouse emissions and promote sustainability[22][23][24]. The Italian government has introduced Building Energy Regulation Codes (BERCs) to drive the market towards more energy-efficient practices[25]. The building energy regulation codes (BERCs) in Italy are governed by the Legislative Decree (LD) 192/05, which was later modified by LD 311/06 and LD 63/2013. This decree is Italy's national building energy code and sets standards for thermal energy efficiency, as well as establishes the use of energy certificates for compliance. The regulations apply to new buildings and major renovations or energy re-qualification of existing ones. The decree sets energy efficiency standards for all new and existing buildings, including requirements for energy consumption, temperature control systems, and solar energy systems. It also mandates energy efficiency certificates for existing buildings and sets national goals for energy consumption reduction.

Additionally, Italy has implemented local codes for energy efficiency of buildings, with a focus on encouraging energy efficiency practices in the construction sector[26] . These regulations are part of Italy's efforts to comply with the European Union's Energy Performance of Buildings Directive and to promote sustainable and energy-efficient building practices. The implementation of these regulations has been influenced by the European Directive on the Energy Performance of Buildings (EPBD)[27].

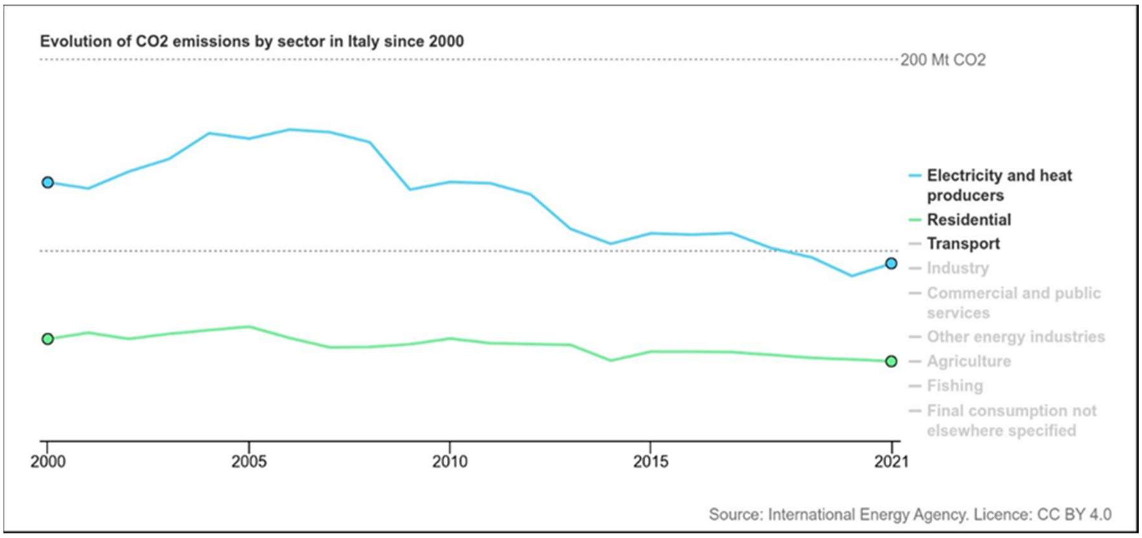

Figure 8: Evolution of CO2 emissions in Italy since 2000.

9.2. DENMARK

In Denmark, the environmental regulations for residential building renovation are primarily governed by the Danish Building Code, BR18[28]. This code contains regulations related to the energy performance of buildings, including those related to major renovations. For instance, if the renovation of a building involves the replacement of a window, a ventilation system, or a roof, the building code defines minimum standards for the energy performance of the new component. The code ensures that the existing building stock continuously becomes more energy efficient and guarantees that energy savings are implemented when it is economically feasible for the owners. The building code is revised every five years to encompass and align with new technological developments in the construction industry[29].

The Danish building regulation addresses the environmental impact by implementing measures to reduce greenhouse gas emissions and promote sustainability in the construction industry. The government has proposed a voluntary sustainability program to improve sustainability performance in the industry[30]. Additionally, a national strategy has been introduced to require life cycle assessments (LCA) of new buildings and compliance with specific CO2e limit values [31]. The Danish Parliament has also passed a Climate Act and an action plan to create a Circular Economy (CE) in Denmark, which includes focusing on the life cycle of buildings, integrating LCA, and operationalizing Life Cycle Sustainability Assessment (LCSA)[32].

Furthermore, the Danish Road Directorate (DRD) considers climate and environmental impact in the planning phase of infrastructure projects, aiming to balance factors such as cost, time, and environmental impact, and to maintain biodiversity and protect the surrounding environment[6][33]. Overall, the Danish building regulation emphasises the importance of reducing environmental impact and transitioning to more sustainable practices in the construction industry.

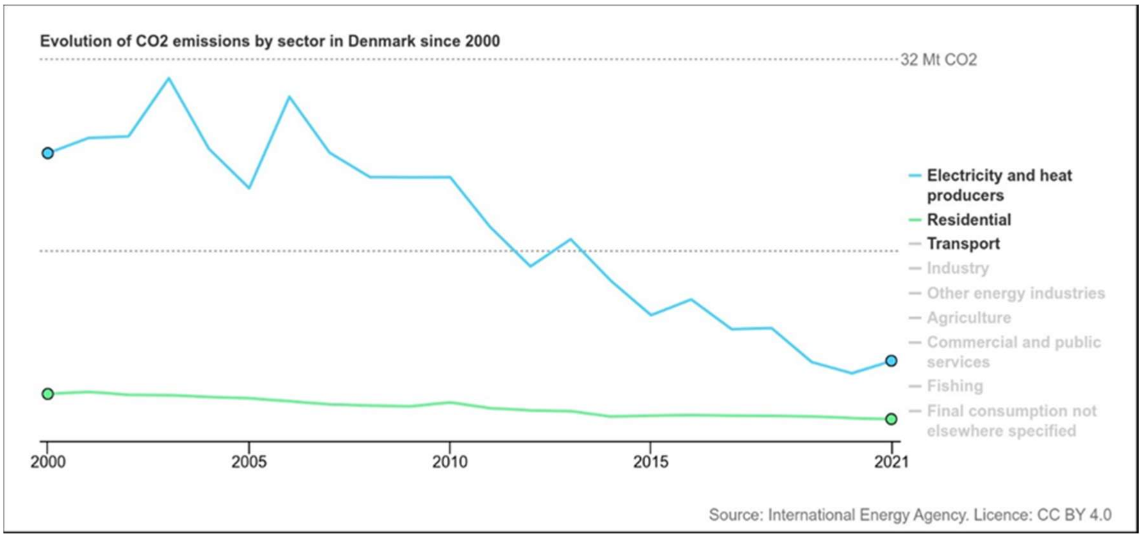

Figure 9: Evolution of CO2 emissions in Denmark since 2000.

9.3. SLOVENIA

In Slovenia, there are significant environmental regulations governing residential building renovations. These rules are guided by the Energy Act, which mandates the Energy Performance Certificate (Energy ID) for both new and existing buildings. The Spatial Planning Act outlines energy performance goals, while the Building Act establishes energy efficiency standards and requirements for building permits.[34]

The country has put forth a comprehensive long-term strategy for energy renovation of buildings up to 2050. The aim is to enhance the energy efficiency and decarbonization of existing building stock. This strategy includes innovative financing mechanisms and aligns with the Integrated National Energy and Climate Plan (NECP or NEKP). Slovenia has also committed to reducing emissions from buildings by 70% from 2005 levels by 2030, in accordance with the EU Green Deal.[35]

Slovenian building codes, like PURES 2010, set minimum standards for existing buildings, applying to both new constructions and significant renovations. The strategy for renovating existing buildings to nearly zero-energy levels is outlined in the Slovenian national plan for nearly zero-energy buildings (NZEB).[36][37]

Funding for sustainable construction and renovation of buildings is allocated through the National Recovery and Resilience Plan. Moreover, the Act on Energy Efficiency and the Decree on Green Public Procurement introduce energy efficiency criteria and mandate the disclosure of energy performance indicators when selling or renting a building. These regulations also encompass initiatives, awareness campaigns, and supplementary policies aimed at enhancing the existing building stock and encouraging sustainable construction practices while reducing greenhouse gas emissions from buildings.[38]

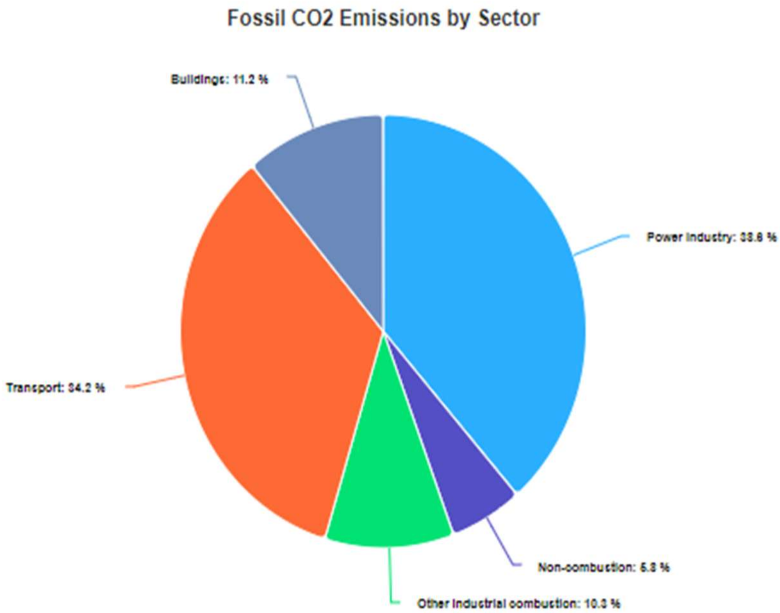

Figure 10: Slovenia Fossil CO2 emissions by sector

10. Conclusions

In conclusion the guidelines packages presented through this deliverable are a valuable resource for promoting energy efficiency renovations in social housing across different EU countries. The different approaches through financial, technical, environmental, and social considerations could help stakeholders, policy makers and users to generate investments in energy efficiency within the social housing sector, contributing to the overall mission of the project and working towards the European Green Deal.

The importance of complying with local and national policies and funding programs have been taken in consideration for the development of this guidelines, and its replicability approach give them even more value, to overcome barriers on energy efficient investments and set up a favourable framework to ensure financing. By implementing the guidelines presented in the report, we can take a significant step towards reducing greenhouse gas emissions and promoting energy efficiency across the EU housing sector.

Ultimately, this deliverable will be continued towards Deliverable 3.10 on M38. Where a Life Cycle Assessment and Social Life Cycle Assessment will be presented as use cases in the 3 pilot partners.

11. References

[1] https://www.nasdaq.com/market-activity/index/spx/historical

[2] https://www.lseg.com/en/data-analytics

[3] https://fred.stlouisfed.org

[4] https://www.ecb.europa.eu/pub/pdf/fsr/ecb.fsr202305~65f8cb74d7.en.pdf.

[5] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

[6] Implementation of the EPBD - Italy, Status in 2020

[7] Energy Performance of Buildings Directive

[8] https://www.stateofhousing.eu/The_State_of_Housing_in_Europe_2023.pdf

[9] Title: Buildings - International Energy Agency (IEA); Publisher: International Energy Agency (IEA); URL: https://www.iea.org/energy-system/buildings

[10] Title: European Green Deal; Publisher: European Commission URL: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[11] Title: European Renovation Wave; Publisher: European Commission; URL: https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1727

[12] Title: Paris Agreement; Publisher: United Nations; URL for Paris Agreement: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[13] Title: United Nations Sustainable Development Goals (SDGs); Publisher: United Nations; URL for Sustainable Development Goals (SDGs): https://sdgs.un.org/goals

[14] Title: Green Buildings Pact; Publisher: European Commission; URL: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/green-building-pact_en

---

[15] Title: EN 15804 - Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products; Publisher: European Committee for Standardization (CEN) URL: https://www.cen.eu/work/areas/environment/cws/Documents/Brochure_EN_15804.pdf

[16] ACAN-The Carbon Footprint of Construction; URL: https://www.architectscan.org/_files/ugd/b22203_c17af553402146638e9bc877101630f3.pdf?index=true

[17] Source: IEA 2022. All rights reserved. Adapted from "Tracking Clean Energy Progress" (IEA 2022f).

[18] Source: IEA 2021. All rights reserved. Adapted from 'Roadmap for Energy-Efficient Buildings and Construction in the Association of Southeast Asian Nations. (IEA 2022e).

[19] EN 15804:2012 + A1:2013, Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products, CEN, Brussels

[20] EN 15978:2011, Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method, CEN, Brussels.

[21] *CIRCE foundation and contributors. D4.3. - LCA-LCC study for technical results and demo cases. BuildHeat project GA N. 680658, November 2018*

[22] Fabio, Fantozzi., Caterina, Gargari., Massimo, Rovai., Giacomo, Salvadori. (2019). Energy Upgrading of Residential Building Stock: Use of Life Cycle Cost Analysis to Assess Interventions on Social Housing in Italy. Sustainability, 11(5):1452-. doi: 10.3390/SU11051452

[23] Graziano, Salvalai., Gabriele, Masera., Marta, Maria, Sesana. (2015). Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study. Renewable & Sustainable Energy Reviews, 42:1245-1259. doi: 10.1016/J.RSER.2014.10.038

[24] Riccardo, Pollo. (2017). The Housing Retrofit Market in Italy: Constraints and Barriers to Development. 765-772. doi: 10.1007/978-3-319-30746-6_59

[25] (n.d.). *Building Codes Assistance Project*. Italy. https://bcapcodes.org/italy/

[26]Graziano, Salvalai., Gabriele, Masera., Marta, Maria, Sesana. (2015). Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study. Renewable & Sustainable Energy Reviews, doi: 10.1016/J.RSER.2014.10.038

[27] (n.d.). *European Directive on the Energy Performance of Buildings (EPBD)* . EPB Center. https://epb.center/epb-standards/energy-performance-buildings-directive-epbd.

[28] (n.d.). Building Regulations 2018 (BR18). International Energy Agency. https://www.iea.org/policies/2511-building-regulations-2018-br18

[29] (n.d.). *Regulating energy efficiency in buildings*. State of Green. https://stateofgreen.com/en/news/regulating-energy-efficiency-in-buildings/

---

[30] Amalie, Palme, Hammershøy., Per, Sieverts, Nielsen., Nanna, Brøgger, Overgård. (2022). Macro-level changes: a voluntary sustainability program to influence the danish building industry. Journal of Green Building, 17(4):19-39. doi: 10.3992/jgb.17.4.19

[31] B., Tozan., E.E., Stapel., C., D., Sorensen., Harpa, Birgisdottir. (2022). The influence of EPD data on LCA results. IOP conference series, 1078(1):012105-012105. doi: 10.1088/1755-1315/1078/1/012105

[32] Vibeke, Grupe, Larsen., Nicola, Tollin., Valentina, Antoniucci., Morten, Birkved., Peter, Andreas, Sattrup., T., Holmboe., Giuliano, Marella. (2022). Filling the gaps Circular transition of affordable housing in Denmark. IOP conference series, 1078(1):012078-012078. doi: 10.1088/1755-1315/1078/1/012078

[33] Erik, Stoklund, Larsen., M.S., Lagergaard., Agnete, Jørgensen., Barbara, MacAulay., Jimmi, Laursen. (2022). Development of requirements for design and steps for protection of the environment, illustrated by two major bridge projects in Denmark. Structure and Infrastructure Engineering, 18(10-11):1398-1409. doi: 10.1080/15732479.2022.2044355

[34] Todorović, I. (2020, July 27). Slovenia drafts energy efficiency law, submits buildings renovation strategy. Balkan Green Energy News. https://balkangreenenergynews.com/slovenia-drafts-energy-efficiency-law-submits-buildings-renovation-strategy-by-2050/

[35] Long-term energy renovation strategy for 2050. (n.d.). Retrieved January, 2024, from https://energy.ec.europa.eu/system/files/2021-08/sl_ltrs_2020_en_0.pdf

[36] Implementation of the EPBD in Slovenia – Status in 2020 - CA. (n.d.). Confluence.external-Share.com. Retrieved February 22, 2024, from https://confluence.external-share.com/content/267c175a-32e9-4999-965f-b007aea1b59e/1861813055/2209349633

[37] National plan for increasing the number of nearly zero-energy buildings in accordance with Article 9 of the Recast EPBD 1 Slovenia. (2014). https://energy.ec.europa.eu/system/files/2018-11/slovenia_en_version_1.pdf

[38] European Commission. (2018). Energy performance of buildings directive. energy.ec.europa.eu. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

[1] Fabio, Fantozzi., Caterina, Gargari., Massimo, Rovai., Giacomo, Salvadori. (2019). Energy Upgrading of Residential Building Stock: Use of Life Cycle Cost Analysis to Assess Interventions on Social Housing in Italy. Sustainability, 11(5):1452-. doi: 10.3390/SU11051452

[2] Graziano, Salvalai., Gabriele, Masera., Marta, Maria, Sesana. (2015). Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study. Renewable & Sustainable Energy Reviews, 42:1245-1259. doi: 10.1016/J.RSER.2014.10.038

[3] Riccardo, Pollo. (2017). The Housing Retrofit Market in Italy: Constraints and Barriers to Development. 765-772. doi: 10.1007/978-3-319-30746-6_59

[4] (n.d.). *Building Codes Assistance Project*. Italy. https://bcapcodes.org/italy/

[5] Graziano, Salvalai., Gabriele, Masera., Marta, Maria, Sesana. (2015). Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study. Renewable & Sustainable Energy Reviews, doi: 10.1016/J.RSER.2014.10.038

[6] (n.d.). *European Directive on the Energy Performance of Buildings (EPBD)* . EPB Center. https://epb.center/epb-standards/energy-performance-buildings-directive-epbd.